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**Lin et al.**

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(54) **ELECTROPHORETIC DISPLAY DEVICE AND DRIVING METHOD THEREOF**


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| | |
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| ***G02F 1/1676*** | (2019.01) |
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(58) **Field of Classification Search**

None

See application file for complete search history.

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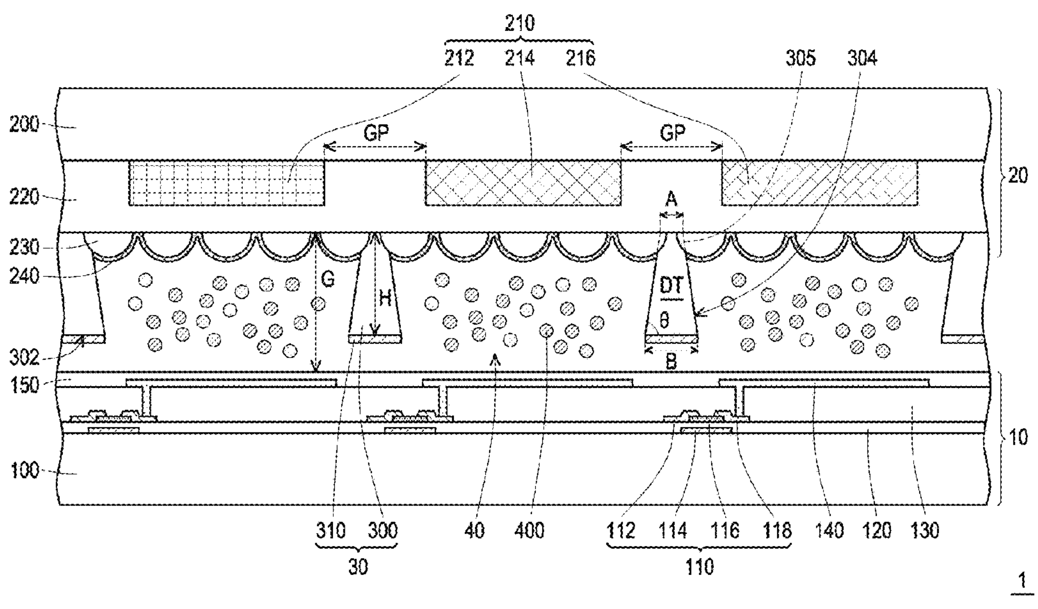
(57) **ABSTRACT**


An electrophoretic display device includes a first component substrate, a second component substrate, a display medium layer, and an isolation structure. The first component substrate includes a first carrier and a plurality of pixel electrodes. The pixel electrodes are arranged in an array on the first carrier. The second component substrate includes a second carrier and at least one common electrode. The at least one common electrode is overlapped with the pixel electrodes. The display medium layer and the isolation structure are located between the first carrier and the second carrier. The display medium layer includes a plurality of charged particles. The isolation structure includes a barrier structure and an isolation electrode. The isolation electrode is formed on a bottom surface of the barrier structure and adjacent to the display medium layer.


**16 Claims, 11 Drawing Sheets**



(51) **Int. Cl.**

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|---|---|
| ***G02F 1/1335*** | (2006.01) |
| ***G02F 1/1675*** | (2019.01) |

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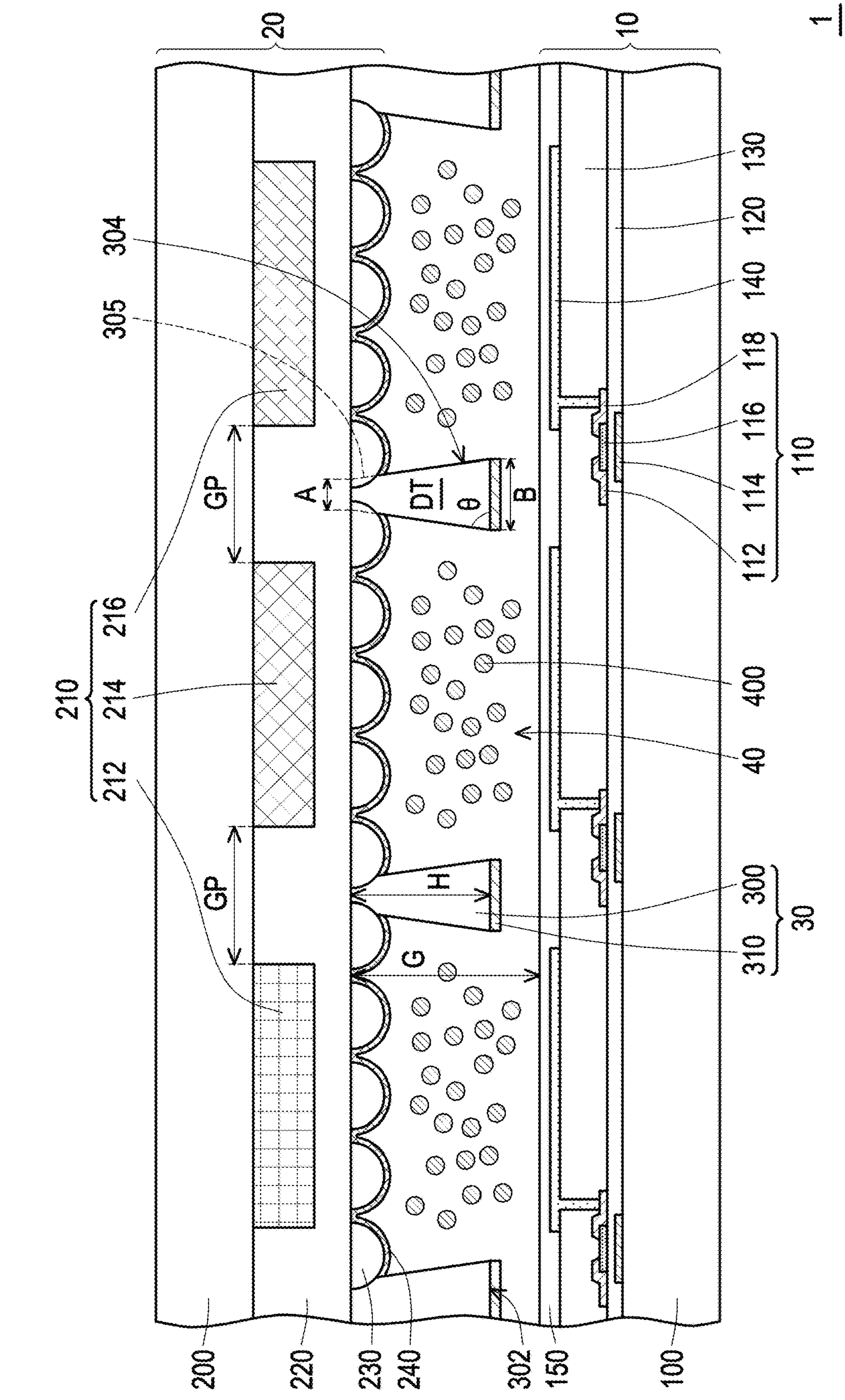

1
20
10
130
120
140
118
116
114
112
110
304
305
216
214
212
210
GP
GP
A
DT
θ
B
H
G
400
40
300
310
30
200
220
230
240
302
150
100

FIG. 1A

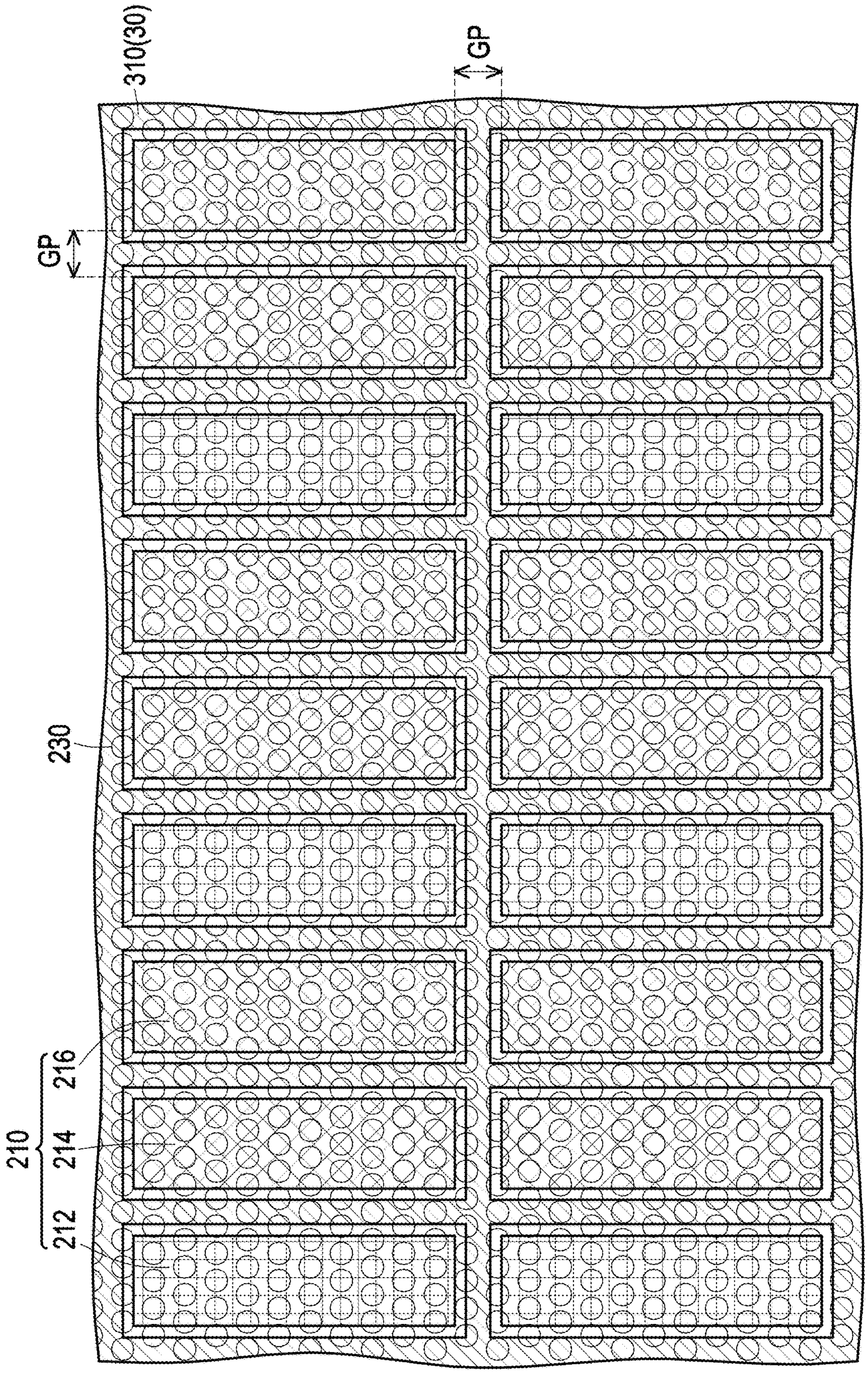
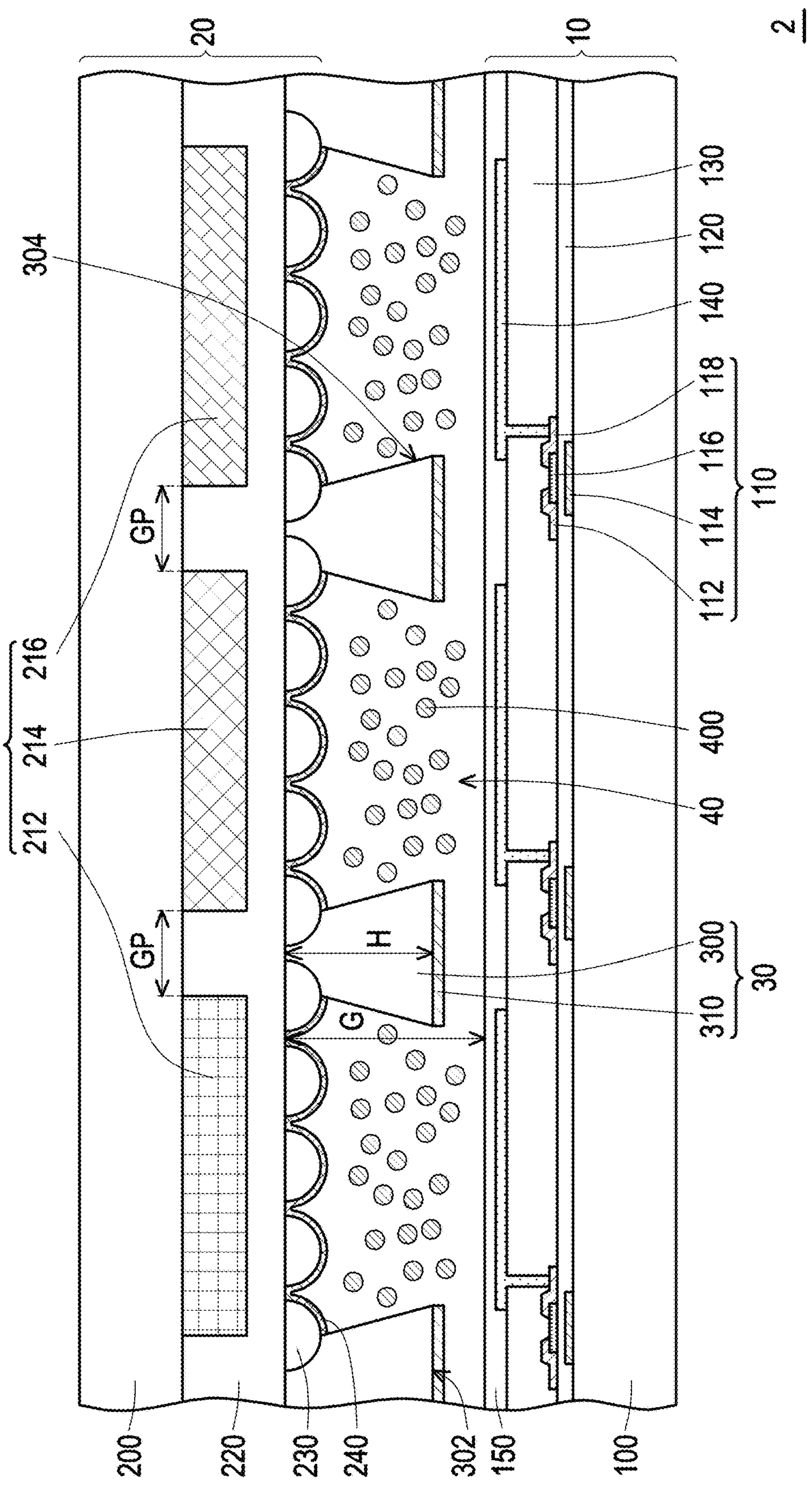



FIG. 1B


2
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150
100

FIG. 2A

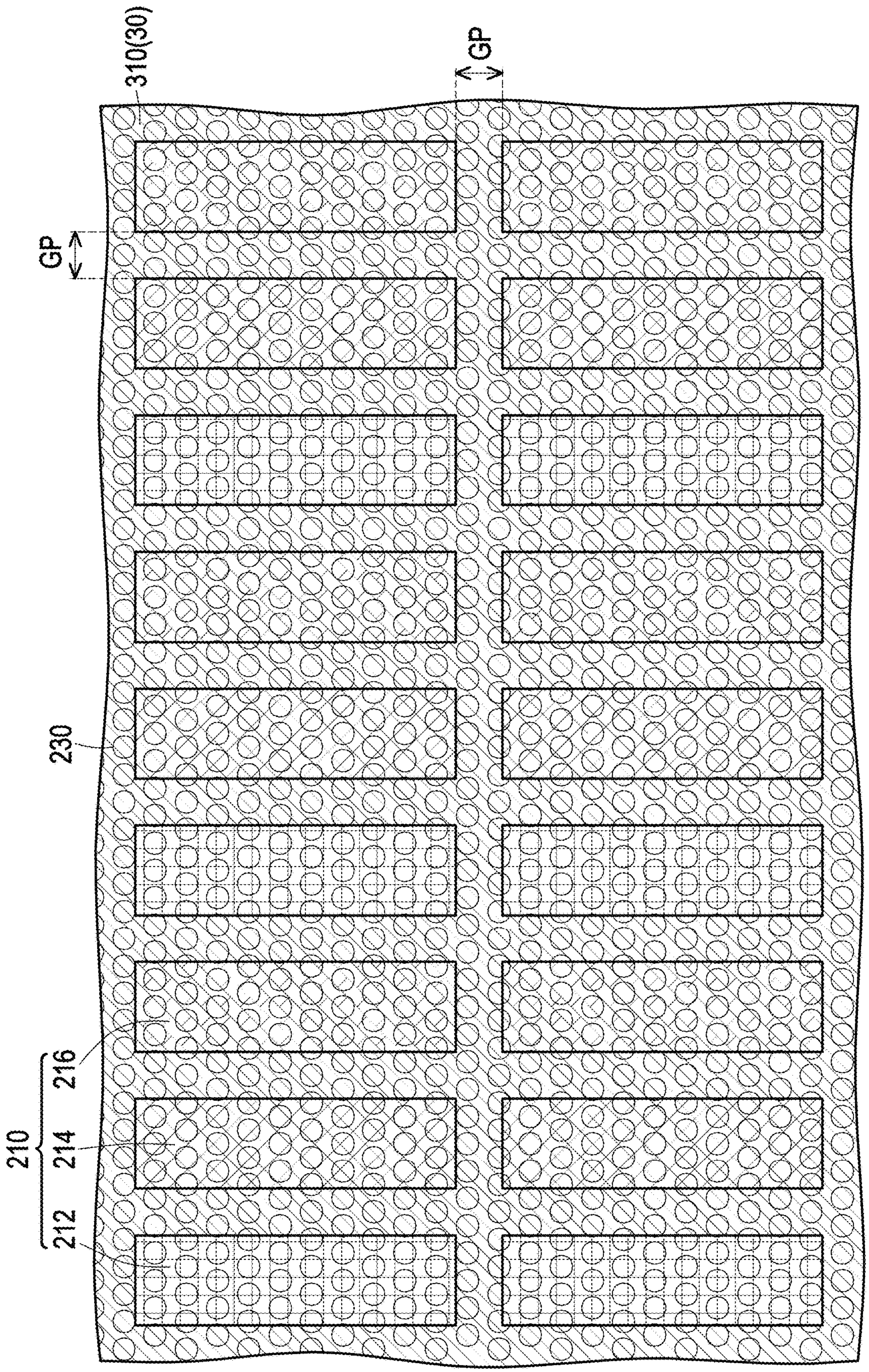



FIG. 2B

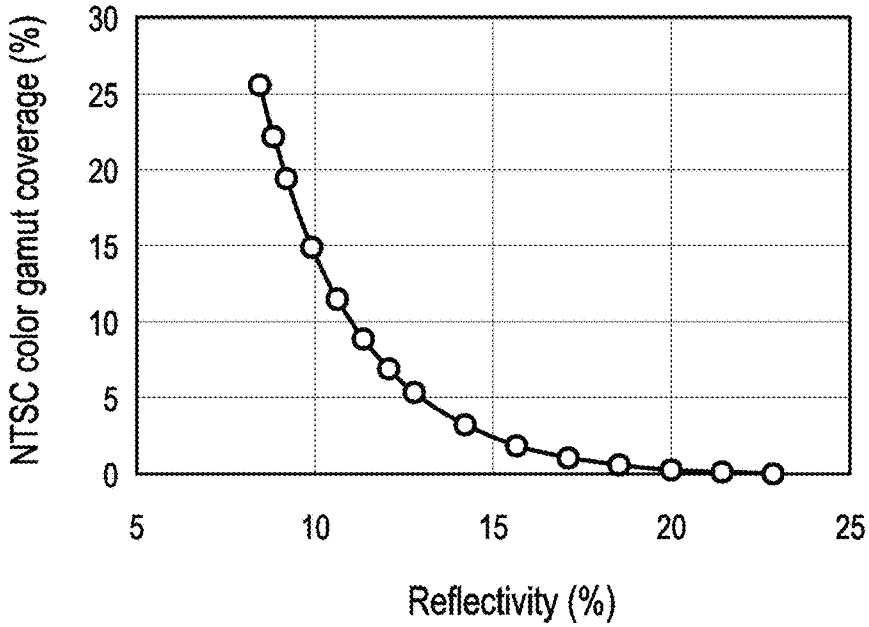

NTSC color gamut coverage (%)
30
25
20
15
10
5
0
5
10
15
20
25
Reflectivity (%)

FIG. 3A

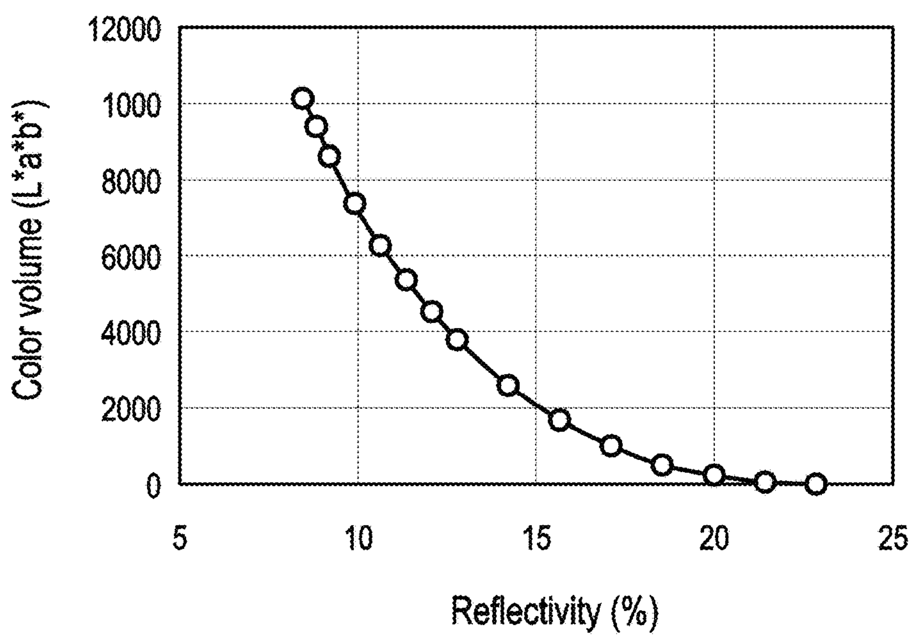

Color volume (L*a*b*)
12000
1000
8000
6000
4000
2000
0
5
10
15
20
25
Reflectivity (%)

FIG. 3B

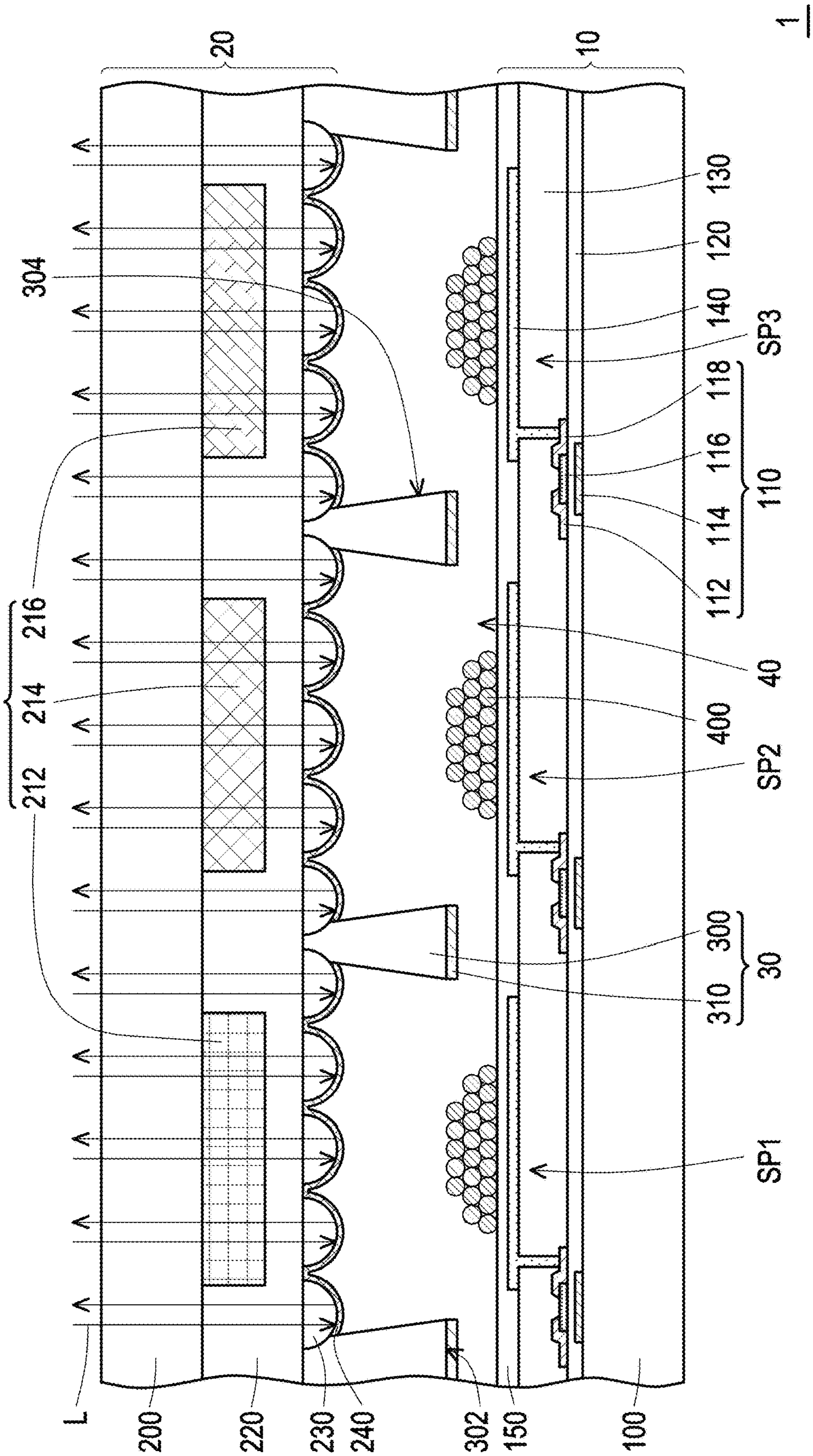
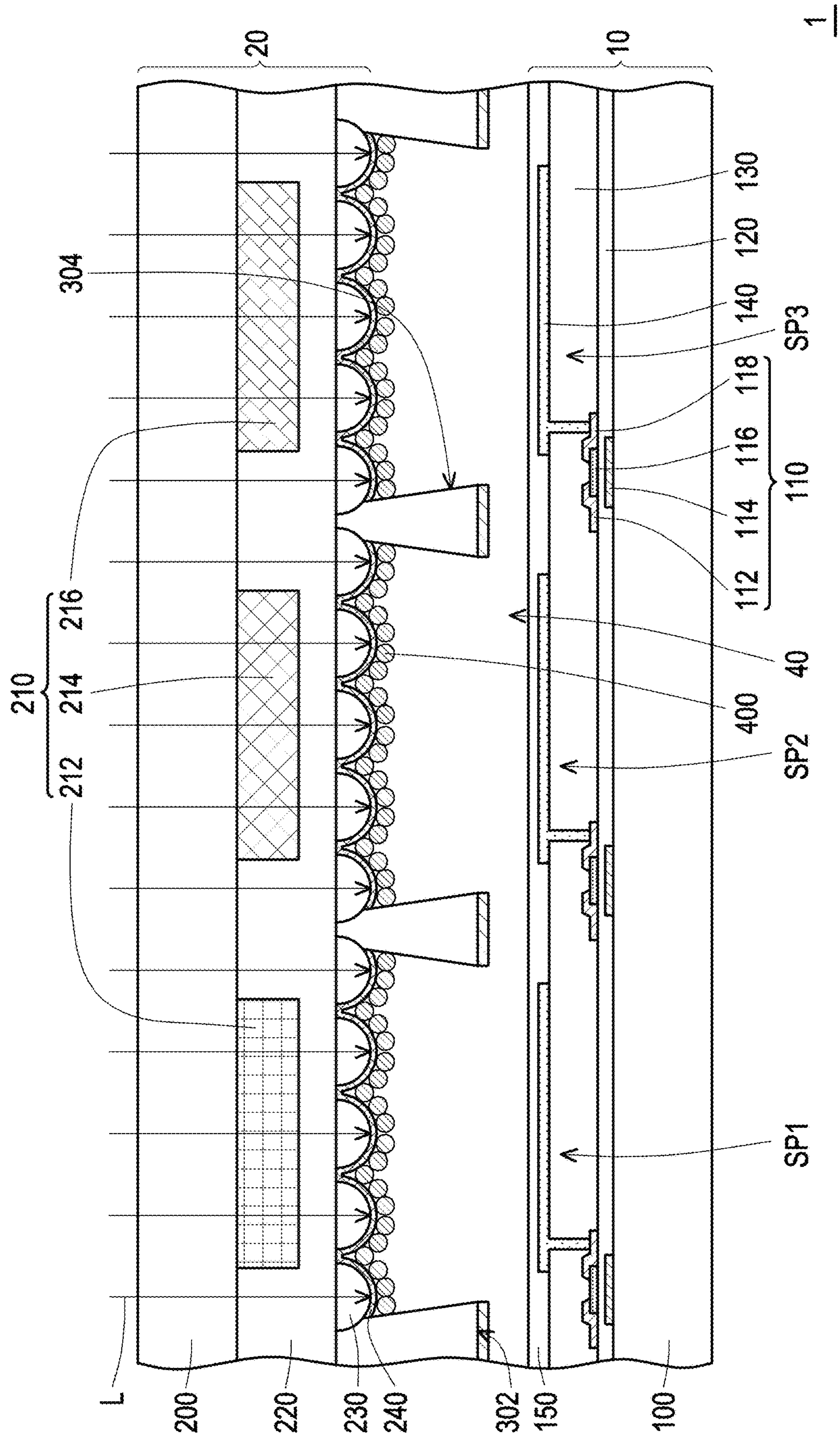

1
10
20
130
120
140
SP3
118
116
110
114
112
40
400
SP2
300
30
310
SP1
304
216
210
214
212
L
200
220
230
240
302
150
100

FIG. 4A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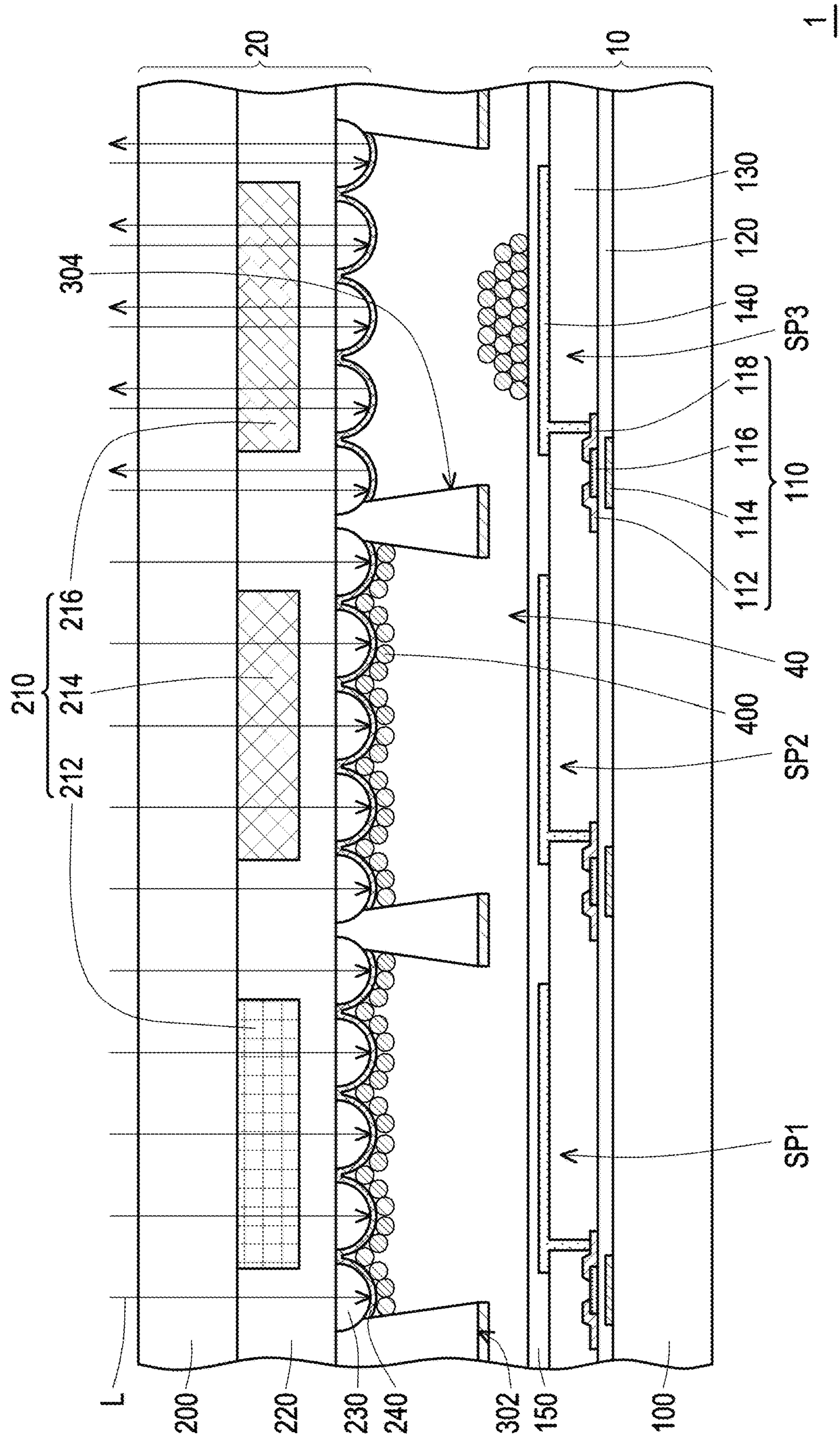
10
304
130
120
140
SP3
118
116
110
114
112
210
216
214
212
40
400
SP2
SP1
L
200
220
230
240
302
150
100

FIG. 4B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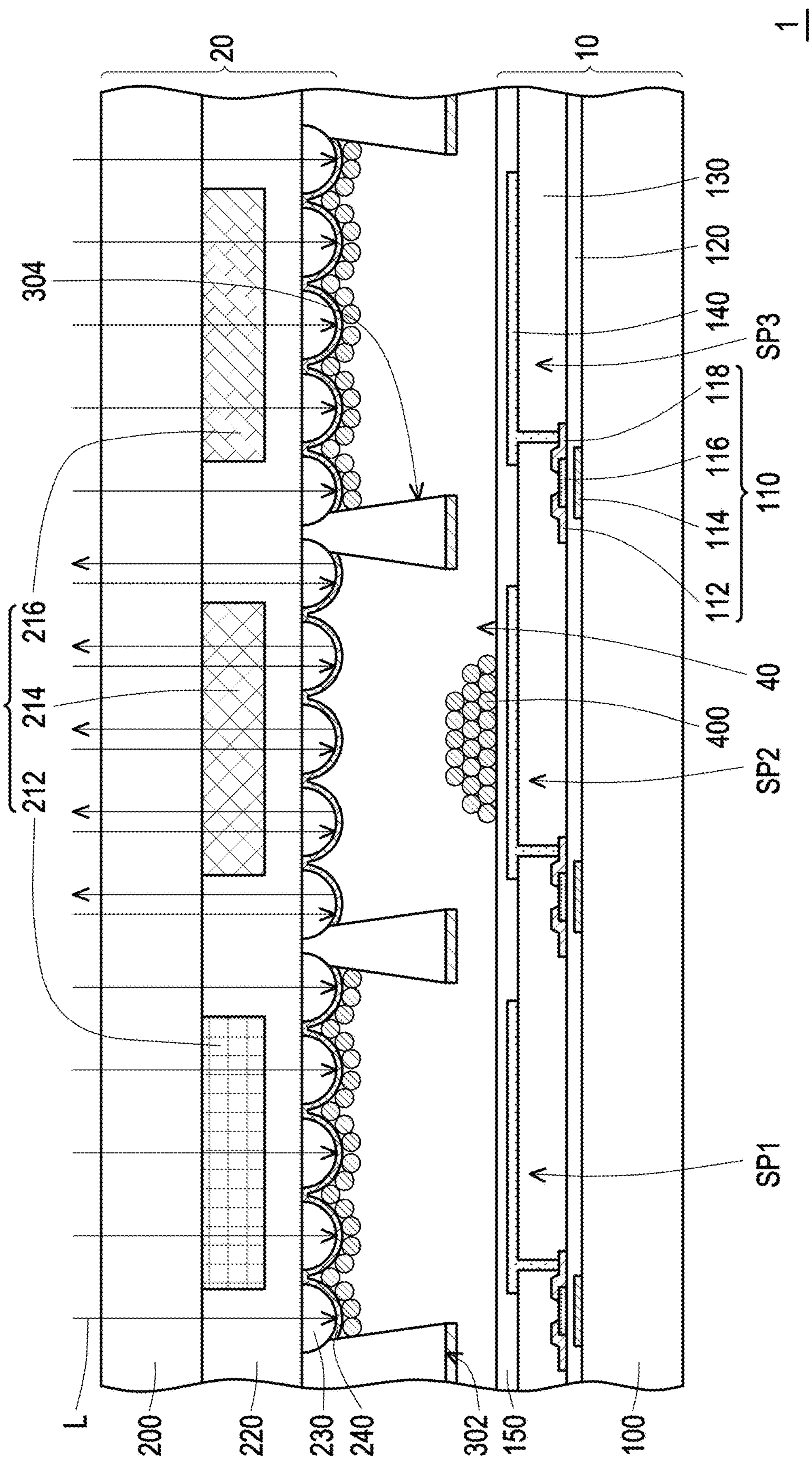
304
130
120
140
SP3
118
116
110
114
112
210
216
214
212
40
400
SP2
SP1
L
200
220
230
240
302
150
100

FIG. 4C


1
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10
304
210
212
214
216
130
120
140
SP3
118
116
114
112
110
40
400
SP2
SP1
L
200
220
230
240
302
150
100

FIG. 4D

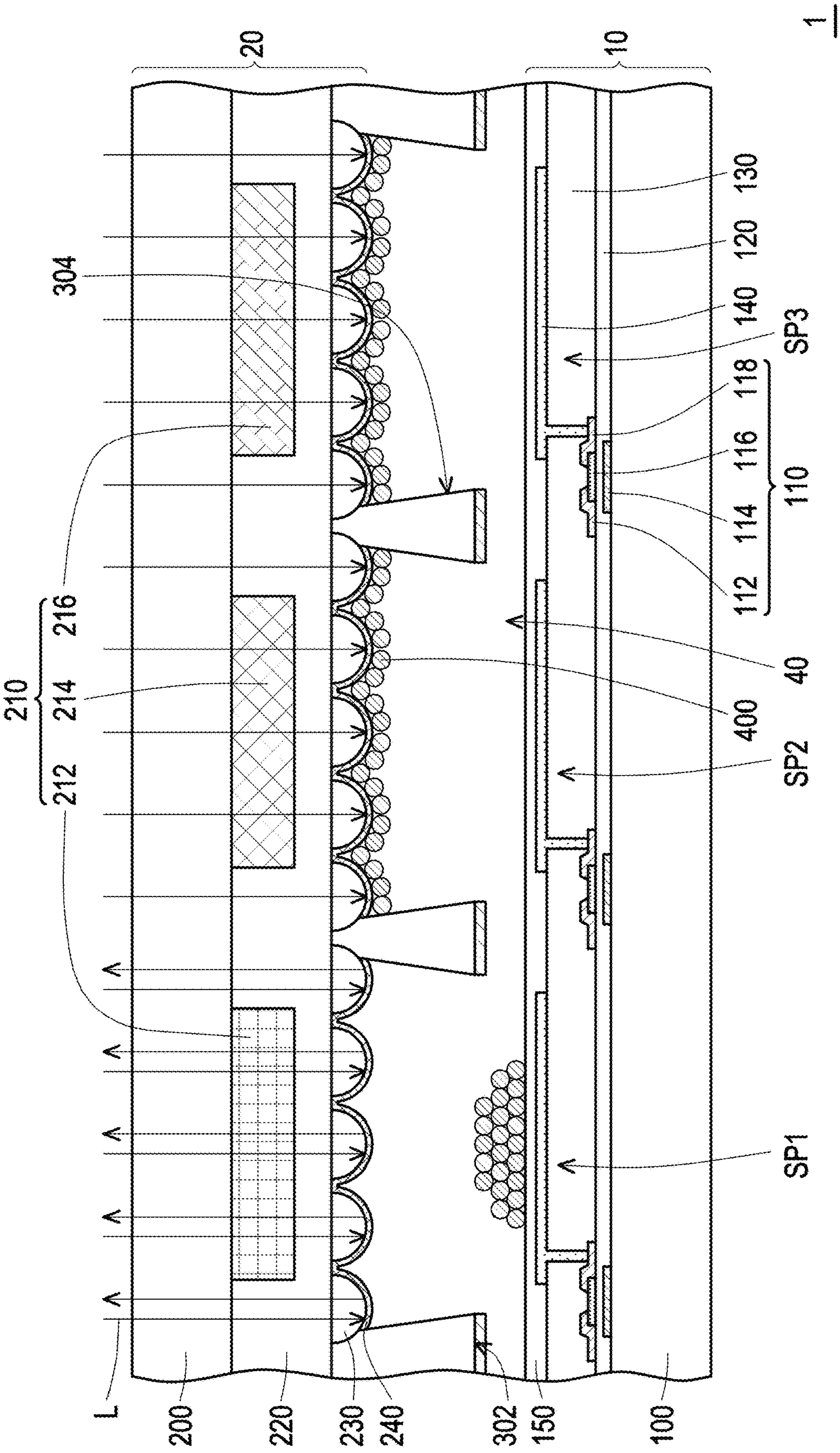
1
20
10
130
120
140
SP3
118
116
114
112
110
304
210
212
214
216
400
40
SP2
SP1
L
200
220
230
240
302
150
100

FIG. 4E

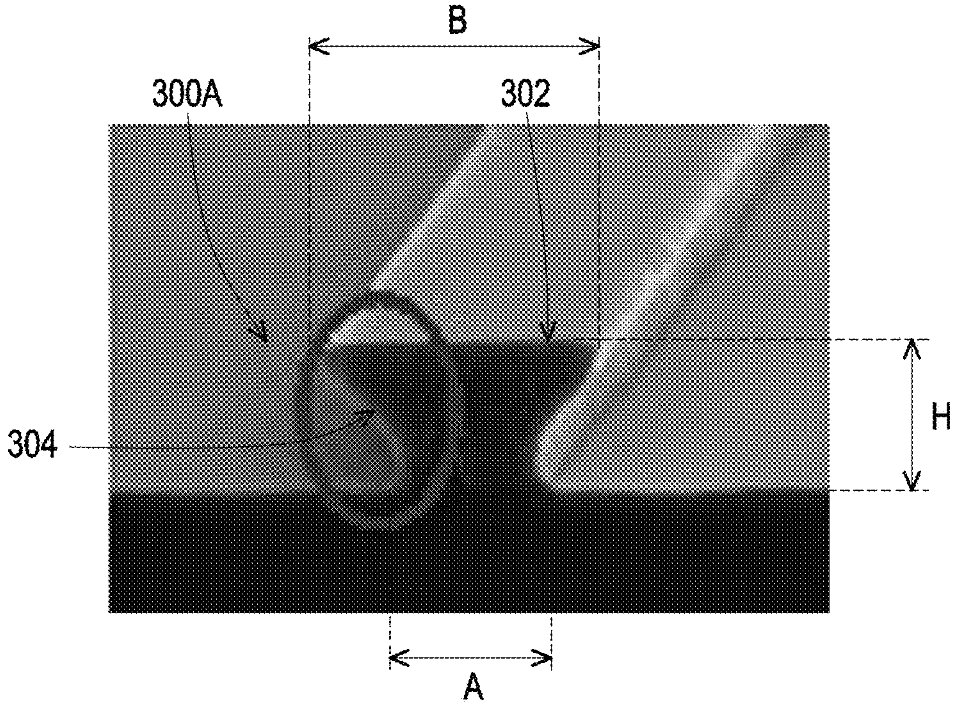


FIG. 5

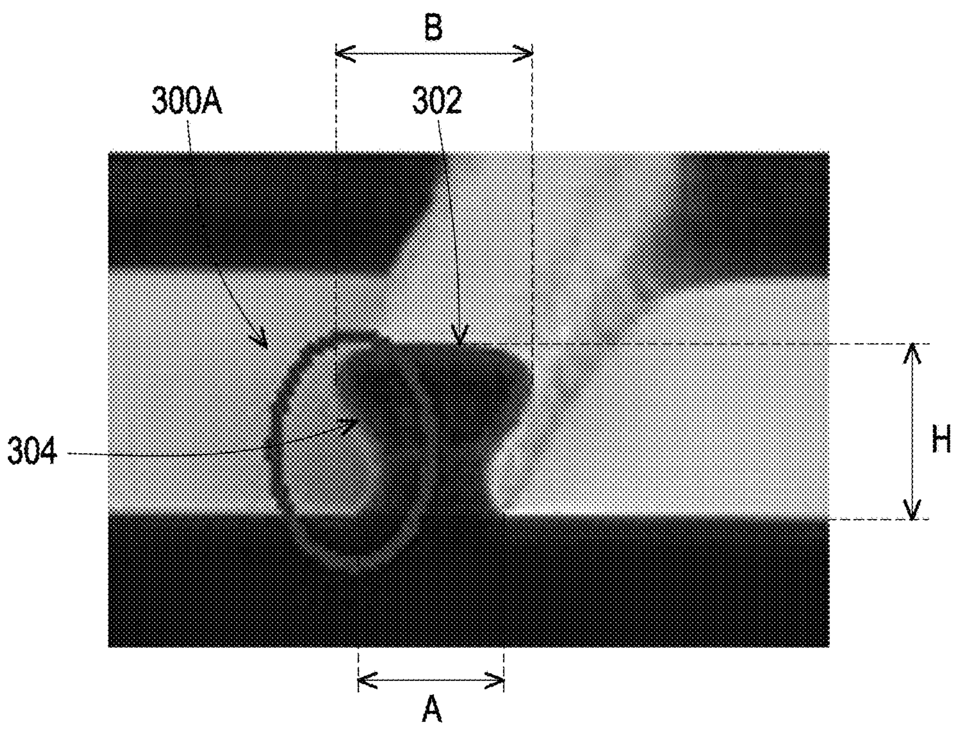


FIG. 6

# ELECTROPHORETIC DISPLAY DEVICE AND DRIVING METHOD THEREOF

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application Ser. No. 111111585, filed on Mar. 28, 2022. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

## BACKGROUND

### Technical Field

The disclosure relates to an electrophoretic display device and a driving method thereof.

### Description of Related Art

In recent years, due to the ongoing vigorous development of various display technologies, after continuous research and development, products, such as electrophoretic displays, liquid crystal displays, plasma displays, organic light emitting diode (OLED) displays, and so forth, have been gradually commercialized and applied to display devices having various sizes and occupying various areas. With the increasing popularity of portable electronic products, flexible displays, e.g., electronic paper (e-paper), electronic book (e-book), and so on, have gradually attracted the attention of the market. Generally, the e-paper and the e-books display images by adopting the electrophoretic display technology. In the electrophoretic display provided in the related art, charged particles in a display medium are applied to reflect an external light source, thereby enabling sub-pixels to display a desired grayscale.

## SUMMARY

The disclosure provides an electrophoretic display device capable of solving an issue of interference between sub-pixels.

The disclosure provides a driving method of an electrophoretic display device for solving an issue of interference between sub-pixels.

At least one embodiment of the disclosure provides an electrophoretic display device that includes a first component substrate, a second component substrate, a display medium layer, and an isolation structure. The first component substrate includes a first carrier and a plurality of pixel electrodes, and the pixel electrodes are arranged in an array on the first carrier. The second component substrate includes a second carrier and at least one common electrode, and the at least one common electrode is overlapped with the pixel electrodes. The display medium layer is located between the first carrier and the second carrier and includes a plurality of charged particles. The isolation structure includes a barrier structure and an isolation electrode. The isolation electrode is formed on a bottom surface of the barrier structure and adjacent to the display medium layer.

At least one embodiment of the disclosure provides a driving method of an electrophoretic display device, and the driving method includes following steps. The electrophoretic display device is provided. A first voltage difference between one of the pixel electrodes and the at least one common electrode is generated. A second voltage difference between the one of the pixel electrodes and the isolation electrode is generated, so that an electric field repelling the charged particles is generated on the isolation electrode.

To make the aforementioned more comprehensible, several embodiments accompanied with drawings are described in detail as follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure.

FIG. **1**A is a schematic cross-sectional view illustrating an electrophoretic display device according to an embodiment of the disclosure.

FIG. **1**B is a schematic top view illustrating the electrophoretic display device depicted in FIG. **1**A.

FIG. **2**A is a schematic cross-sectional view illustrating an electrophoretic display device according to an embodiment of the disclosure.

FIG. **2**B is a schematic top view illustrating the electrophoretic display device depicted in FIG. **2**A.

FIG. **3**A illustrates data of relationship between an NTSC color gamut coverage and a reflectivity of an electrophoretic display device according to some embodiments of the disclosure.

FIG. **3**B illustrates data of relationship between a color volume (L*a*b)) and a reflectivity of an electrophoretic display device according to some embodiments of the disclosure.

FIG. **4**A to FIG. **4**E are schematic cross-sectional views illustrating a driving method of an electrophoretic display device according to an embodiment of the disclosure.

FIG. **5** is a micrograph of a barrier structure according to an embodiment of the disclosure.

FIG. **6** is a micrograph of a barrier structure according to an embodiment of the disclosure.

## DESCRIPTION OF THE EMBODIMENTS

FIG. **1**A is a schematic cross-sectional view illustrating an electrophoretic display device according to an embodiment of the disclosure. FIG. **1**B is a schematic top view illustrating the electrophoretic display device depicted in FIG. **1**A.

With reference to FIG. **1**A and FIG. **1**B, an electrophoretic display device **10** includes a first component substrate **10**, a second component substrate **20**, an isolation structure **30**, and a display medium layer **40**.

The first component substrate **10** includes a first carrier and a plurality of pixel electrodes **140**. In this embodiment, the first component substrate further includes a plurality of active components **110**, a first insulation layer **120**, a second insulation layer **130**, and a third insulation layer **150**.

A material of the first carrier **100** includes glass, quartz, organic polymer, or an opaque/reflective material (e.g., a conductive material, metal, wafer, ceramics, or other applicable materials), or other applicable materials. When the conductive material or metal is applied, the first carrier **100** is covered by an insulation layer (not shown) to avoid short circuit problems.

The active components **110** are arranged in an array on the first carrier **100**. Each active component **110** includes a gate **114**, a channel layer **116**, a source **112**, and a drain **118**. The gate **114** is overlapped with the channel layer **116**, and the first insulating layer **120** is sandwiched between the gate **114** and the channel layer **116**. The source **112** and the drain **118** are located on the first insulating layer **120** and electrically connected to the channel layer **116**.

In this embodiment, the active components **110** are, for instance, bottom-gate thin film transistors (TFTs), which should however not be construed as a limitation in the disclosure. In other embodiments, the active components **110** may also be top-gate TFTs, double-gate TFTs, or TFTs of other types.

In some embodiments, materials of the gate **114**, the source **112**, and the drain **118** include, for instance, chromium, gold, silver, copper, tin, lead, hafnium, tungsten, molybdenum, neodymium, titanium, tantalum, aluminum, zinc, and other metals, alloy of the above metals, oxides of the above metals, nitrides of the above metals, a combination of the above, or other conductive materials. In some embodiments, a material of the channel layer **116** includes, for instance, amorphous silicon, polysilicon, microcrystalline silicon, monocrystalline silicon, an organic semiconductor material, an oxide semiconductor material, e.g., indium zinc oxide (IZO), indium gallium zinc oxide (IGZO), other suitable materials, or a combination of the above materials, other suitable materials, or a combination of the above materials.

The second insulation layer **130** is located on the active components **110**, and the second insulation layer **130** has an opening overlapping the drains **118** of the active components **110**.

The pixel electrodes **140** are arranged in an array on the first carrier **100**. In this embodiment, the pixel electrodes **140** are located on the second insulation layer **130** and fill the opening of the second insulation layer **130**, so as to be electrically connected to the drains **118** of the active components **110**. In this embodiment, each sub-pixel includes a corresponding pixel electrode **140** and a corresponding active component **110**. In some embodiments, the pixel electrodes **140** includes a transparent electrode (e.g., indium tin oxide (ITO), IZO, aluminum tin oxide (ATO), aluminum zinc oxide (AZO), IGZO, or other transparent conductive materials), a reflective electrode (e.g., metal), or other conductive materials. The third insulation layer **150** is located on the pixel electrodes **140** and covers the pixel electrodes **140**.

The second component substrate **20** includes a second carrier **200** and at least one common electrode **240**. In this embodiment, the second component substrate **20** further includes a color filter component **210**, a planarization layer **220**, and a plurality of protruding micro-structures **230**.

A material of the second carrier **200** includes glass, quartz, organic polymer, or other applicable transparent materials.

The color filter component **210** is located between the first carrier **100** and the second carrier **200**. In this embodiment, the color filter component **210** is formed on the second carrier **200**, which should however not be construed as a limitation in the disclosure. In other embodiments, other insulation layers, passivation layers, and/or buffer layers are sandwiched between the color filter component **210** and the second carrier **200**. In this embodiment, the color filter component **210** includes a blue filter component **212**, a green filter component **214**, and a red filter component **216**. The blue filter component **212**, the green filter component **214**, and the red filter component **216** are separated from one another.

The planarization layer **220** is located on the color filter component **210**. The planarization layer **220** covers the color filter component **210**. The protruding micro-structures **230** are formed on the planarization layer **220**, and the protruding micro-structures **230** protrude toward the display medium layer **40**. In this embodiment, the protruding micro-structures **230** are arranged in an array on the planarization layer **220**. In some embodiments, the protruding micro-structures **230** include a photoresist material, and a method of forming the protruding micro-structures **230** includes performing a photolithographic process once. For instance, the protruding micro-structures **230** are formed by performing the photolithographic process for three times, and one third of the amount of the protruding micro-structures **230** is formed each time; therefore, the protruding micro-structures **230** formed by performing the photolithographic process each time may have greater pitches therebetween, thereby improving the manufacturing yield. The planarization layer **220** and the protruding micro-structures **230** include transparent materials. For instance, the planarization layer **220** and the protruding micro-structures **230** include resin, photoresist materials, or other transparent materials.

The at least one common electrode **240** is formed on the protruding micro-structures **230**. In this embodiment, the at least one common electrode **240** is directly formed on the protruding micro-structures **230**, which should however not be construed as a limitation in the disclosure. In other embodiments, a buffer layer may be included between the at least one common electrode **240** and the protruding micro-structures **230**. The at least one common electrode **240** has an undulating surface corresponding to the protruding micro-structures **230**. The at least one common electrode **240** is conformal to the protruding micro-structures **230**, for instance. The at least one common electrode **240** is overlapped with the pixel electrodes **140**. In some embodiments, the at least one common electrode **240** includes a transparent electrode, e.g., ITO, IZO, ATO, AZO, IGZO, or other conductive materials.

The display medium layer **40** is located between the first carrier **100** and the second carrier **200**. The display medium layer **40** includes a plurality of charged particles **400**. The charged particles **400** are, for instance, particles carrying negative or positive charges, and the charged particles **400** include a light absorbing material. On the condition that no electric field is applied, the charged particles **400** are dispersed in an electrophoresis solution of the display medium layer **40**.

The isolation structure **30** is located between the first carrier **100** and the second carrier **200**. In this embodiment, the isolation structure **30** is located between the protruding micro-structures **230** and the third insulation layer **150**. The isolation structure **30** includes a barrier structure **300** and an isolation electrode **310**.

The barrier structure **300** is directly formed on the protruding micro-structures **230** and/or the at least one common electrode **240**. The barrier structure **300** includes a reflective material. In some embodiments, the barrier structure **300** includes a photoresist material and reflective particles dispersed in the photoresist material, e.g., porous (or air-containing) silicon oxide ($SiO_2$), titanium oxide ($TiO_2$), aluminum oxide ($Al_2O_3$), calcium carbonate ($CaCO_3$), barium sulfate ($BaSO_4$), zirconia ($ZrO_2$), metal-coated polymer particles, hollow polymer particles, or other particles that can reflect light. In other embodiments, the barrier structure **300** includes a photoresist material and a reflective layer formed on the surface of the photoresist material. In some embodiments, a method of forming the barrier structure **300** includes a photolithographic process.

A portion of the display medium layer **40** is located between a bottom surface **302** of the barrier structure **300** and the first component substrate **10**. In this embodiment, an included angle θ between a side surface **304** of the barrier structure **300** and the bottom surface **302** of the barrier structure **300** is less than 90 degrees; hence, a line width of the barrier structure **300** increases while the barrier structure approaches the first component substrate **10**, thereby reducing the probability of the mutual interference between the charged particles **400** of different sub-pixels. Specifically, since the line width of the barrier structure **300** is relatively large when the barrier structure **300** is relatively close to the first component substrate **10**, a length of a gap between the barrier structure **300** and the third insulation layer **150** is relatively long, so that the charged particles **400** are less likely to pass through the gap between the barrier structure **300** and third insulation layer **150**. As such, an issue of uneven brightness resulting from the different number of the charged particles **400** in different sub-pixels may be prevented. In some embodiments, the included angle θ includes an acute angle or a rounded angle.

According to the embodiment depicted in FIG. **1**A, in a cross-sectional structure of the electrophoretic display device **1**, a virtual trapezoid DT includes the bottom surface **302** of the barrier structure **300**, the side surfaces **304** of the barrier structure **300**, virtual connecting lines **305** extending from the side surfaces **304** of the barrier structure to the planarization layer **220**, and a surface of the planarization layer **220** between the virtual connecting lines **305**. Here, a width of the surface of the planarization layer **220** between the virtual connecting lines **305** is A, a width of the bottom surface **302** of the barrier structure **300** is B, a height of the virtual trapezoid DT is H, and $A\ 2H\times\cot(80°)\leq B\leq A\ 2H\times\cot(10°)$. In some embodiments, a maximum thickness of the barrier structure **300** is H, a maximum thickness of the display medium layer **40** is G, and $0.55G\leq H\leq 0.95G$. In some embodiments, the width B is greater than the width A, wherein the width B is, for instance, 1 micrometer to 500 micrometers, and the width A is, for instance, 0.67 micrometer to 100 micrometers. In some embodiments, the thickness is, for instance, 0.95 micrometer to 35.2 micrometers.

In the cross-sectional view in FIG. **1**A, the at least one common electrode **240** includes a plurality of portions separated by the barrier structure **300**; however, in some embodiments, the at least one common electrode **240** partially extends between the barrier structure **300** and the protruding micro-structures **230** (not shown), so that the portions of the at least one common electrode **240** are connected to each other.

The isolation electrode **310** is formed on the bottom surface **302** of the barrier structure **300** and adjacent to the display medium layer **40**. In this embodiment, the isolation electrode **310** directly contacts the display medium layer **40**, which should however not be construed as a limitation in the disclosure. In this embodiment, a width of the isolation electrode **310** is less than or equal to the bottom surface **302** of the barrier structure **300**. In other words, the isolation electrode **310** completely or partially covers the bottom surface **302** of the barrier structure **300**. In some embodiments, the isolation electrode **310** includes a transparent electrode (e.g., ITO, IZO, ATO, AZO, IGZO, or other transparent conductive materials), a reflective electrode (e.g., metal), or other conductive materials. The isolation electrode **310**, the at least one common electrode **240**, and the pixel electrodes **140** are separated from one another. Therefore, different voltages may be applied to the isolation electrode **310**, the at least one common electrode **240**, and the pixel electrodes **140**, so as to create an electric field between the isolation electrode **310** and the at least one common electrode **240**, between the isolation electrode **310** and the pixel electrodes **140**, and between the pixel electrodes **140** and the at least one common electrode **240**.

With reference to FIG. **1**A and FIG. **1**B, in the top view in FIG. **1**B, the isolation structure **30** has a mesh shape. In this embodiment, both the barrier structure **300** and the isolation electrode **310** of the isolation structure **30** have a mesh shape. An orthogonal projection of the isolation structure **30** on the second carrier **200** is overlapped with a gap GP of an orthogonal projection of the color filter component **210** on the second carrier **200**. In other words, the orthogonal projection of the isolation structure **30** on the second carrier **200** is located among orthogonal projections of the blue filter component **212**, the green filter component **214**, and the red filter component **216** on the second carrier **200**.

The orthogonal projection of the isolation structure **30** on the second carrier **200** is smaller than or equal to the gap GP of the orthogonal projection of the color filter component **210** on the second carrier **200**. In this embodiment, the orthogonal projection of the isolation structure **30** on the second carrier **200** is smaller than the gap GP of the orthogonal projection of the color filter component **210** on the second carrier **200**; hence, when the electrophoretic display device **1** is observed from the front (observed from top to bottom in FIG. **1**A), a portion of the at least one common electrode **240** and the protruding micro-structures **230** are located between the color filter component **210** and the isolation structure **30**, so as to enhance white light reflected by the electrophoretic display device **1** and accordingly improve reflectivity and brightness of the electrophoretic display device **1**.

FIG. **2**A is a schematic cross-sectional view illustrating an electrophoretic display device according to an embodiment of the disclosure. FIG. **2**B is a schematic top view illustrating the electrophoretic display device depicted in FIG. **2**A.

It should be mentioned that the reference numbers and some content in the embodiment depicted in FIG. **2**A and FIG. **2**B are derived from the reference numbers and some content in the embodiment depicted in FIG. **1**A and FIG. **1**B, where the same or similar reference numbers serve to represent the same or similar components, and the description of the same technical content is omitted. For the description of the omitted part, reference may be made to the foregoing embodiments, which will not be repeated here.

The main difference between an electrophoretic display device **2** depicted in FIG. **2**A and FIG. **2**B and the electrophoretic display device **1** depicted in FIG. **1**A and FIG. **1**B lies in that the orthogonal projection of the isolation structure **30** of the electrophoretic display device **2** on the second carrier **200** is greater than or equal to the gap GP of the orthogonal projection of the color filter component **210** on the second carrier **200**.

In this embodiment, when the electrophoretic display device **2** is observed from the front (observed from top to bottom in FIG. **2**A), there is no common electrode **240** nor protruding micro-structures **230** between the color filter component **210** and the isolation structure **30**, so as to reduce the white light reflected by the electrophoretic display device **2** and accordingly improve the color volume of the electrophoretic display device **2**.

FIG. **3**A illustrates data of relationship between an NTS C color gamut coverage and a reflectivity of an electrophoretic display device according to some embodiments of the disclosure. FIG. **3**B illustrates data of relationship between a color volume (L*a*b) and a reflectivity of an electrophoretic display device according to some embodiments of the disclosure. The structure of the electrophoretic display device in FIG. **3**A and FIG. **3**B may be referred to as the electrophoretic display device **1** in FIG. **1**A and FIG. **1**B and the electrophoretic display device **2** in FIG. **2**A and FIG. **2**B.

As shown in FIG. **3**A and FIG. **3**B, the reflectivity of the electrophoretic display device is adjusted by changing the width of the isolation structure and/or the width of the gap of the color filter component. In some embodiments, the larger the width of the isolation structure and the width of the gap of the color filter component, the greater the reflectivity of the electrophoretic display device; the smaller the width of the isolation structure and the width of the gap of the color filter component, the lower the reflectivity of the electrophoretic display device.

From the data shown in FIG. **3**A and FIG. **3**B, it is known that the NTSC color gamut coverage and the color volume (L*a*b*) of the electrophoretic display device increase together with the decrease in the reflectivity of the electrophoretic display device.

FIG. **4**A to FIG. **4**E are schematic cross-sectional views illustrating a driving method of an electrophoretic display device according to an embodiment of the disclosure. It should be mentioned that the reference numbers and some content in the embodiment depicted in FIG. **4**A and FIG. **4**B are derived from the reference numbers and some content in the embodiment depicted in FIG. **1**A and FIG. **1**B, where the same or similar reference numbers serve to represent the same or similar components, and the description of the same technical content is omitted. For the description of the omitted part, reference may be made to the foregoing embodiments, which will not be repeated here.

With reference to FIG. **4**A, a first voltage difference is generated between at least one of the pixel electrodes **140** and the at least one common electrode **240**, so that an electric field attracting the charged particles is generated on the at least one of the pixel electrodes **140**. A second voltage difference is generated between the at least one of the pixel electrodes **140** and the isolation electrode **310**, so that an electric field repelling the charged particles **400** is generated on the isolation electrode **310**.

In some embodiments, the charged particles **400** carry negative charges, a first voltage is applied to the pixel electrode **140** of a first sub-pixel SP**1**, the pixel electrode **140** of a second sub-pixel SP**2**, and the pixel electrode **140** of a third sub-pixel SP**3**, a second voltage is applied to the at least one common electrode **240**, and a third voltage is applied to the isolation electrode **310**, where the third voltage is less than the second voltage, the second voltage is less than the first voltage, and the first voltage, the second voltage, and the third voltage are all less than 30 volts and greater than −30 volts.

In some embodiments, the charged particles **400** carry positive charges, the first voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1**, the pixel electrode **140** of the second sub-pixel SP**2**, and the pixel electrode **140** of the third sub-pixel SP**3**, the second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**, where the third voltage is greater than the second voltage, the second voltage is greater than the first voltage, and the first voltage, the second voltage, and the third voltage are all less than 30 volts and greater than −30 volts.

In this embodiment, a refractive index of the protruding micro-structures **230** (e.g., greater than or equal to 1.52 and less than or equal to 2.4) is higher than a refractive index of the electrophoresis solution of the display medium layer **40** (e.g., greater than or equal to 1 and less than or equal to 1.52).

In some embodiments, when the refractive index of the at least one common electrode **240** is greater than or equal to the refractive index of the protruding micro-structures **230**, the total reflection of an external light beam L occurs at an interface between the display medium layer **40** and the at least one common electrode **240**.

In some embodiments, when the refractive index of the at least one common electrode **240** ranges from the refractive index of the protruding micro-structures **230** to the refractive index of the electrophoresis solution of the display medium layer **40**, the total reflection of the external light beam L occurs at both the interface between the protruding micro-structures **230** and the at least one common electrode **240** and the interface between the display medium layer **40** and the at least one common electrode **240**.

In some embodiments, when the refractive index of the at least one common electrode **240** is less than or equal to the refractive index of the electrophoresis solution of the display medium layer **40**, the total reflection of the external light beam L occurs at the interface between the protruding micro-structures **230** and the at least one common electrode **240**.

A portion of the external light beam **1**, passes through the blue filter component **212**, the green filter component **214**, and/or the red filter component **216** to generate the color to be displayed. With reference to FIG. **4**A, the external light beam L passes through the blue filter component **212**, the green filter component **214**, and the red filter component **216** and enables the first sub-pixel SP**1**, the second sub-pixel SP**2**, and the third sub-pixel SP**3** to respectively generate blue, green, and red light. As shown in FIG. **4**A, a portion of the external light beam L does not pass through the color filter component **210** and is reflected at the interface between the display medium layer **40** and the at least one common electrode or on the surface of the isolation structure **30**. If the external light beam L is white light, the light reflected by the isolation structure **30** is white light.

With reference to FIG. **4**B, a third voltage difference is generated between at least one of the pixel electrodes **140** and the at least one common electrode **240**, so that the electric field repelling the charged particles is generated on the at least one of the pixel electrodes **140**. A fourth voltage difference is generated between the at least one of the pixel electrodes **140** and the isolation electrode **310**, so that the electric field repelling the charged particles **400** is generated on the isolation electrode **310**.

In some embodiments, the charged particles **400** carry the negative charges, a fourth voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1**, the pixel electrode **140** of the second sub-pixel SP**2**, and the pixel electrode **140** of the third sub-pixel SP**3**, the second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**, where the third voltage is less than the fourth voltage, the fourth voltage is less than the second voltage, and the second voltage, the third voltage, and the fourth voltage are all less than 30 volts and greater than −30 volts.

In some embodiments, the charged particles **400** carry the positive charges, the fourth voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1**, the pixel electrode **140** of the second sub-pixel SP**2**, and the pixel electrode **140** of the third sub-pixel SP**3**, the second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**, where the third voltage is greater than the fourth voltage, the fourth voltage is greater than the second voltage, and the second voltage, the third voltage, and the fourth voltage are all less than 30 volts and greater than −30 volts.

in FIG. **4**B, the charged particles **400** are attracted to the interface between the display medium layer **40** and the at least one common electrode and absorb the external light beam L, so that the first sub-pixel SP**1**, the second sub-pixel SP**2**, and the third sub-pixel SP**3** appear to be in a dark state.

With reference to FIG. **4**C, the first voltage is applied to the pixel electrode **140** of the third sub-pixel SP**3**, and the fourth voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1** and the pixel electrode **140** of the second sub-pixel SP**2**. The second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**.

In this embodiment, the electric field attracting the charged particles **400** is generated on the pixel electrode **140** of the third sub-pixel SP**3**, and the electric field repelling the charged particles **400** is generated on the pixel electrode **140** of the first sub-pixel SP**1**, the pixel electrode **140** of the second sub-pixel SP**2**, and the isolation electrode **310**.

As shown in FIG. **4**C, the external light beam L is reflected after passing through the red filter component **216** and allows the third sub-pixel SP**3** to generate the red light. In FIG. **4**C, the charged particles **400** are attracted to the interface between the display medium layer **40** of the first sub-pixel SP**1** and the second sub-pixel SP**2** and the at least one common electrode and absorb the external light beam L, so that the first sub-pixel SP**1** and the second sub-pixel SP**2** appear to be in the dark state.

With reference to FIG. **4**D, the first voltage is applied to the pixel electrode **140** of the second sub-pixel SP**2**, and the fourth voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1** and the pixel electrode **140** of the third sub-pixel SP**3**. The second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**.

In this embodiment, the electric field attracting the charged particles **400** is generated on the pixel electrode **140** of the second sub-pixel SP**2**, and the electric field repelling the charged particles **400** is generated on the pixel electrode **140** of the first sub-pixel SP**1**, the pixel electrode **140** of the third sub-pixel SP**3**, and the isolation electrode **310**.

As shown in FIG. **4**D, the external light beam L is reflected after passing through the green filter component **214** and allows the second sub-pixel SP**2** to generate the green light. In FIG. **4**D, the charged particles **400** are attracted to the interface between the display medium layer **40** of the first sub-pixel SP**1** and the third sub-pixel SP**3** and the at least one common electrode **240** and absorb the external light beam L, so that the first sub-pixel SP**1** and the third sub-pixel SP**3** appear to be in the dark state.

With reference to FIG. **4**E, the first voltage is applied to the pixel electrode **140** of the first sub-pixel SP**1**, and the fourth voltage is applied to the pixel electrode **140** of the second sub-pixel SP**2** and the pixel electrode **140** of the third sub-pixel SP**3**. The second voltage is applied to the at least one common electrode **240**, and the third voltage is applied to the isolation electrode **310**.

In this embodiment, the electric field attracting the charged particles **400** is generated on the pixel electrode **140** of the first sub-pixel SP**1**, and the electric field repelling the charged particles **400** is generated on the pixel electrode **140** of the second sub-pixel SP**2**, the pixel electrode **140** of the third sub-pixel SP**3**, and the isolation electrode **310**.

As shown in FIG. **4**E, the external light beam L is reflected after passing through the blue filter component **212** and allows the first sub-pixel SP**1** to generate the blue light. In FIG. **4**E, the charged particles **400** are attracted to the interface between the display medium layer **40** of the second sub-pixel SP**2** and the third sub-pixel SP**3** and the at least one common electrode and absorb the external light beam L, so that the second sub-pixel SP**2** and the third sub-pixel SP**3** appear to be in the dark state.

FIG. **5** is a micrograph of a barrier structure according to an embodiment of the disclosure.

With reference to FIG. **5**, a barrier structure **300**A is formed by performing a photolithographic process. In this embodiment, the viscosity of the photoresist material forming the barrier structure **300**A is 86 mPa·s, and the solid content (content of the reflective particles) is 65%. In this embodiment, the resultant barrier structure **300**A has an optical density (OD) of 0.03/μm, a reflectivity (R % for a light beam with a wavelength of 450 nm) greater than 50% (e.g., 83.5%), and a transmittance (TT % for a light beam with a wavelength of 500 nm) greater than 10% (e.g., 20.2%). In some embodiments, the shape of the resultant barrier structure **300**A is adjusted by adjusting the properties (e.g., the viscosity, the composition, and so on) of the photoresist material. As shown in FIG. **5**, the included angle between the side surface **304** of the barrier structure **300**A and the bottom surface **302** (the upper surface in FIG. **5**) of the barrier structure **300**A is less than 90 degrees. In FIG. **5**, the ratio of the width B of the bottom surface **302** of the barrier structure **300**A to the width A of the top surface (the lower surface in FIG. **5**) is about 20 μm:14.4 μm. The thickness H of the harrier structure **300**A in FIG. **5** is greater than 15 micrometers.

FIG. **6** is a micrograph of a barrier structure according to an embodiment of the disclosure.

With reference to FIG. **6**, a barrier structure **300**B is formed by performing a photolithographic process. In this embodiment, the viscosity of the photoresist material forming the harrier structure **300**B is 113 mPa·s, and the solid content (content of the reflective particles) is 65%. In this embodiment, the resultant barrier structure **300**B has the OD of 0.08/μm, the reflectivity (R % for the light beam with a wavelength of 450 nm) less than 50% (e.g., 47.4%), and the transmittance (TT % for the light beam with a wavelength of 500 nm) less than 10% (e.g., 4.2%). In some embodiments, the shape of the resultant barrier structure **300**B is adjusted by adjusting the properties (e.g., the viscosity, the composition, and so on) of the photoresist material. As shown in FIG. **6**, a rounded angle exists between the side surface **304** of the barrier structure **300**B and the bottom surface **302** (the upper surface in FIG. **6**) of the barrier structure **300**B. In FIG. **6**, the ratio of the width B of the bottom surface **302** of the barrier structure **300**B to the width A of the top surface (the lower surface in FIG. **6**) is about 20 μm:16.4 μm. The thickness H of the barrier structure **300**B in FIG. **6** is greater than 15 micrometers.

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the disclosure covers modifications and variations provided that they fall within the scope of the following claims and their equivalents.

What is claimed is:

**1**. An electrophoretic display device, comprising:

a first component substrate, comprising:

a first carrier; and

a plurality of pixel electrodes, arranged in an array on the first carrier;

a second component substrate, comprising:

a second carrier; and

at least one common electrode, overlapped with the pixel electrodes;

a display medium layer, located between the first carrier and the second carrier and comprising a plurality of charged particles; and

an isolation structure, located between the first carrier and the second carrier and comprising:

a barrier structure, wherein a width of a bottom portion of the barrier structure is greater than a width of an upper portion of the barrier structure; and

an isolation electrode, formed on a bottom surface of the bottom portion of the barrier structure and adjacent to the display medium layer, wherein a portion of the display medium layer is located between the bottom surface of the bottom portion of the barrier structure and the first component substrate.

**2**. The electrophoretic display device according to claim **1**, wherein a maximum thickness of the barrier structure is H, a maximum thickness of the display medium layer is G, and $0.55G\leq H\leq 0.95G$.

**3**. The electrophoretic display device according to claim **1**, wherein the second component substrate comprises:

a planarization layer; and

a plurality of protruding micro-structures, formed on the planarization layer and protruding toward the display medium layer, wherein the at least one common electrode is formed on the protruding micro-structures.

**4**. The electrophoretic display device according to claim **3**, wherein in a cross-sectional structure of the electrophoretic display device, a virtual trapezoid comprises the bottom surface of the barrier structure, side surfaces of the barrier structure, virtual connecting lines extending from the side surfaces of the barrier structure to the planarization layer, and a surface of the planarization layer between the virtual connecting lines, wherein a width of the surface of the planarization layer between the virtual connecting lines is A, a width of the bottom surface of the barrier structure is B, a height of the virtual trapezoid is H, and $A\ 2H\times\cot(80^\circ)\leq B\leq A\ 2H\times\cot(10^\circ)$.

**5**. The electrophoretic display device according to claim **3**, wherein the barrier structure is directly formed on the protruding micro-structures and/or the at least one common electrode.

**6**. The electrophoretic display device according to claim **3**, wherein the barrier structure has a mesh shape, and the isolation electrode has a mesh shape.

**7**. The electrophoretic display device according to claim **1**, wherein the second component substrate comprises:

a color filter component, located between the first carrier and the second carrier, wherein an orthogonal projection of the isolation structure on the second carrier is overlapped with a gap of an orthogonal projection of the color filter component on the second carrier.

**8**. The electrophoretic display device according to claim **7**, wherein the orthogonal projection of the isolation structure on the second carrier is smaller than or equal to the gap of the orthogonal projection of the color filter component on the second carrier.

**9**. The electrophoretic display device according to claim **1**, wherein an angle less than 90 degrees is included between a side surface of the barrier structure and the bottom surface of the barrier structure.

**10**. The electrophoretic display device according to claim **1**, wherein the barrier structure comprises a reflective material, and the charged particles comprise a light absorbing material.

**11**. A driving method of an electrophoretic display device, comprising:

providing the electrophoretic display device according to claim **1**;

generating a first voltage difference between one of the pixel electrodes and the at least one common electrode; and

generating a second voltage difference between the one of the pixel electrodes and the isolation electrode, so that an electric field repelling the charged particles is generated on the isolation electrode.

**12**. The driving method of the electrophoretic display device according to claim **11**, wherein a first voltage is applied to the one of the pixel electrodes, a second voltage is applied to the at least one common electrode, and a third voltage is applied to the isolation electrode, wherein the third voltage is less than the second voltage, and the second voltage is less than the first voltage, wherein the charged particles carry negative charges, and an electric field attracting the charged particles is generated on the one of the pixel electrodes.

**13**. The driving method of the electrophoretic display device according to claim **12**, further comprising:

generating a third voltage difference between another of the pixel electrodes and the at least one common electrode, wherein a fourth voltage is applied to another of the pixel electrodes, and the second voltage is applied to the at least one common electrode; and

generating a fourth voltage difference between the another of the pixel electrodes and the isolation electrode, so that the electric field repelling the charged particles is generated on the isolation electrode, wherein the third voltage is applied to the isolation electrode, wherein the third voltage is less than the fourth voltage, the fourth voltage is less than the second voltage, and the electric field repelling the charged particles is generated on the another of the pixel electrodes.

**14**. The driving method of the electrophoretic display device according to claim **11**, wherein a first voltage is applied to the one of the pixel electrodes, a second voltage is applied to the at least one common electrode, and a third voltage is applied to the isolation electrode, wherein the third voltage is greater than the second voltage, and the second voltage is greater than the first voltage, wherein the charged particles carry positive charges, and an electric field attracting the charged particles is generated on the one of the pixel electrodes.

**15**. The driving method of electrophoretic display device according to claim **14**, further comprising:

generating a third voltage difference between another of the pixel electrodes and the at least one common electrode, wherein a fourth voltage is applied to the another of the pixel electrodes, and the second voltage is applied to the at least one common electrode; and

generating a fourth voltage difference between the another of the pixel electrodes and the isolation electrode, so that the electric field repelling the charged particles is generated on the isolation electrode, where the third voltage is applied to the isolation electrode, wherein the third voltage is greater than the fourth voltage, the fourth voltage is greater than the second voltage, and the electric field repelling the charged particles is generated on the another of the pixel electrodes.

**16**. An electrophoretic display device, comprising:

a first component substrate, comprising:

a first carrier; and

a plurality of pixel electrodes, arranged in an array on the first carrier;

a second component substrate, comprising:

a second carrier; and

at least one common electrode, overlapped with the pixel electrodes;

a display medium layer, located between the first carrier and the second carrier and comprising a plurality of charged particles; and

an isolation structure, located between the first carrier and the second carrier and comprising:

a barrier structure, wherein the barrier structure defines a plurality of accommodating spaces with narrow bottoms and wide tops, wherein the narrow bottoms of adjacent accommodating spaces are interconnected through an interval space between the isolation structure and the first component substrate, and the display medium layer fills into the accommodating spaces and the interval space; and

an isolation electrode, formed on a bottom surface of barrier structure and adjacent to the display medium layer.

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